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INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference PE18691PC00	FOR FURTHER ACTION See Form PCT/IPEA/416	
International application No. PCT/SE2003/001825	International filing date (*day/month/year*) 25-11-2003	Priority date (*day/month/year*)
International Patent Classification (IPC) or national classification and IPC See Supplemental Box		
Applicant Telefonaktiebolaget LM Ericsson (publ)		

1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 4 sheets, including this cover sheet.
3. This report is also accompanied by ANNEXES, comprising:
   a. ☒ *(sent to the applicant and to the International Bureau)* a total of 13 sheets, as follows:
      - ☒ sheets of the description, claims and/or drawings which have been amended and are the basis of this report and/or sheets containing rectifications authorized by this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions).
      - ☐ sheets which supersede earlier sheets, but which this Authority considers contain an amendment that goes beyond the disclosure in the international application as filed, as indicated in item 4 of Box No. I and the Supplemental Box.

   b. ☐ *(sent to the International Bureau only)* a total of (indicate type and number of electronic carrier(s)) ________, containing a sequence listing and/or tables related thereto, in electronic form only, as indicated in the Supplemental Box Relating to Sequence Listing (see Section 802 of the Administrative Instructions).
4. This report contains indications relating to the following items:
   - ☒ Box No. I — Basis of the report
   - ☐ Box No. II — Priority
   - ☐ Box No. III — Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - ☐ Box No. IV — Lack of unity of invention
   - ☒ Box No. V — Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - ☐ Box No. VI — Certain documents cited
   - ☐ Box No. VII — Certain defects in the international application
   - ☐ Box No. VIII — Certain observations on the international application

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Date of submission of the demand 23-06-2005	Date of completion of this report 28-02-2006
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Supplemental Box

In case the space in any of the preceding boxes is not sufficient.

Continuation of: Cover sheet

INTERNATIONAL PATENT CLASSIFICATION (IPC):

H03F 1/32 (2006.01)
H03F 1/26 (2006.01)

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.
PCT/SE2003/001825

Box No. I Basis of the report

1. With regard to the language, this report is based on:

- [x] the international application in the language in which it was filed
- [ ] a translation of the international application into ____________________, which is the language of a translation furnished for the purposes of:
  - [ ] international search (Rules 12.3(a) and 23.1(b))
  - [ ] publication of the international application (Rule 12.4(a))
  - [ ] international preliminary examination (Rules 55.2(a) and/or 55.3(a))

2. With regard to the elements of the international application, this report is based on *(replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report):*

- [ ] the international application as originally filed/furnished
- [x] the description:
  - pages 1-15 as originally filed/furnished
  - pages* ____________ received by this Authority on ____________
  - pages* ____________ received by this Authority on ____________
- [x] the claims:
  - pages ____________ as originally filed/furnished
  - pages* ____________ as amended (together with any statement) under Article 19
  - pages* 1-13 received by this Authority on 2005-10-31
  - pages* ____________ received by this Authority on ____________
- [x] the drawings:
  - pages 1-8 as originally filed/furnished
  - pages* ____________ received by this Authority on ____________
  - pages* ____________ received by this Authority on ____________
- [ ] a sequence listing and/or any related table(s) – see Supplemental Box Relating to Sequence Listing.

3. [ ] The amendments have resulted in the cancellation of:

- [ ] the description, pages ____________
- [ ] the claims, Nos. ____________
- [ ] the drawings, sheets/figs ____________
- [ ] the sequence listing *(specify)*: ____________
- [ ] any table(s) related to the sequence listing *(specify)*: ____________

4. [ ] This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).

- [ ] the description, pages ____________
- [ ] the claims, Nos. ____________
- [ ] the drawings, sheets/figs ____________
- [ ] the sequence listing *(specify)*: ____________
- [ ] any table(s) related to the sequence listing *(specify)*: ____________

* *If item 4 applies, some or all of those sheets may be marked "superseded."*

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.
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Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1-24	YES
	Claims		NO
Inventive step (IS)	Claims	1-24	YES
	Claims		NO
Industrial applicability (IA)	Claims	1-24	YES
	Claims		NO

2. Citations and explanations (Rule 70.7)

Documents cited in the International Search Report:

D1: US 2003/058959 A1
D2: US 5923712 A
D3: GB 2385730 A
D4: US 5914620 A

The cited documents represent the general state of the art.

The invention defined in claims 1-24, filed with the letter of 2005-10-31, is not disclosed by any of these documents.

The cited prior art does not give any indication that would lead a person skilled in the art to the claimed training method for a power amplifier pre-distorter, power amplifier pre-distorter and base station. Therefore, the claimed invention is not obvious to a person skilled in the art.

Accordingly, the invention defined in claims 1-24 is novel and is considered to involve an inventive step. The invention is industrially applicable.

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CLAIMS

1. A training method for a power amplifier pre-distorter formed by a FIR filter structure including

an individual look-up table for each filter tap, each look-up table representing a discretized polynomial in a variable representing input signal amplitude, and

means for selecting, from each filter tap look-up table, a filter coefficient that depends on the amplitude of a corresponding complex signal value to be multiplied by the filter tap, said training method including the steps of

storing measured unamplified input signal samples and corresponding power amplifier output signal feedback samples; and

determining look-up table filter coefficients for each filter tap by separate independent iterative procedures using said stored samples.

2. The method of claim 1, wherein said iterative procedures are least mean square based.

3. The method of claim 2, including the step of calculating a refined filter coefficient estimate $T_{ql}(b)$ corresponding to a filter tap with a delay q and a signal amplitude bin b from a previous filter coefficient estimate $T_{ql-1}(b)$ in accordance with the equation:

$$T_{ql}(b)=T_{ql-1}(b)+\mu_q\cdot\frac{1}{N_b}\cdot\sum_{|x_{k-q}|\in M_b}\frac{x_k-y_k}{|x_{k-q}|^2}\cdot x_{k-q}^*$$

where

μ_q is a predetermined constant associated with filter tap q,

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N_b is the number of stored input signal samples that have an amplitude that falls within a predetermined window M_b around the center amplitude of bin b,

x_{k-q} is a stored input signal sample that has a delay q,

y_k is a power amplifier output signal feedback sample corresponding to power amplifier input signal sample x_k,

* denotes complex conjugation.

4. The method of claim 2, including the step of calculating a refined filter coefficient estimate $T_{qi}(b)$ corresponding to a filter tap with a delay q and a signal amplitude bin b from a previous filter coefficient estimate $T_{qi-1}(b)$ in accordance with the equation:

$$\begin{cases} T_{qi}(b) = T_{qi-1}(b) + \mu_q \cdot u(b) \dfrac{1}{N_b} \cdot \sum\limits_{|x_{k-q}| \in M_b} (x_k - y_k) \cdot x_{k-q}^* \\ u(b) = \dfrac{1}{\overline{|x_b|}^2} \end{cases}$$

where

μ_q is a constant associated with filter tap q,

N_b is the number of stored input signal samples that have an amplitude that falls within a predetermined window M_b around the center amplitude $\overline{|x_b|}$ of bin b,

x_{k-q} is a stored input signal sample that has a delay q,

y_k is a power amplifier output signal feedback sample corresponding to input signal sample x_k,

* denotes complex conjugation.

5. The method of claim 2, including the step of calculating a refined filter coefficient estimate $T_{ql}(b)$ corresponding to a filter tap with a delay q and a signal amplitude bin b from a previous filter coefficient estimate $T_{ql-1}(b)$ in accordance with the equation:

$$T_{ql}(b) = T_{ql-1}(b) + \mu_q \cdot (x_k - y_k) \cdot \frac{x_{k-q}^{*}}{\left|x_{k-q}\right|^2} : \quad \left|x_{k-q}\right| \in M_b$$

where

μ_q is a constant associated with filter tap q,

x_{k-q} is a stored input signal sample that has that has a delay q and an amplitude that falls within a predetermined window M_b around the center amplitude of bin b,

y_k is a power amplifier output signal feedback sample corresponding to input signal sample x_k,

* denotes complex conjugation.

6. The method of claim 2, including the step of calculating a refined filter coefficient estimate $T_{ql}(b)$ corresponding to a filter tap with a delay q and a signal amplitude bin b from a previous filter coefficient estimate $T_{ql-1}(b)$ in accordance with the equation:

$$\begin{cases} T_{ql}(b) = T_{ql-1}(b) + \mu_q \cdot u(b) \cdot (x_k - y_k) \cdot x_{k-q}^{*} : \quad \left|x_{k-q}\right| \in M_b \\ u(b) = \dfrac{1}{\left|x_b\right|^2} \end{cases}$$

where

μ_q is a constant associated with filter tap q,

x_{k-q} is a stored input signal sample that has a delay q and an amplitude that falls within a predetermined window M_b around the center amplitude $\left|\overline{x_b}\right|$ of bin b,

x_k is a power amplifier input signal sample that y_{k-q} is a power amplifier output signal feedback sample corresponding to input signal sample x_k,

* denotes complex conjugation.

7. A power amplifier pre-distorter formed by a FIR filter structure including

an individual look-up table for each filter tap, each look-up table representing a discretized polynomial in a variable representing input signal amplitude, and

means for selecting, from each filter tap look-up table, a filter coefficient that depends on the amplitude of a corresponding complex signal value to be multiplied by the filter tap, said pre-distorter including

means (50) for storing measured unamplified input signal samples and corresponding power amplifier output signal feedback samples; and

means (48) for determining look-up table filter coefficients for each filter tap by separate independent iterative procedures using said stored samples

8. The pre-distorter of claim 7, including means (48, 50) for implementing said iterative procedures as least mean square based iterative procedures.

9. The pre-distorter of claim 8, including means (48) for calculating a refined filter coefficient estimate $T_{qi}(b)$ corresponding to a filter tap with a delay q and a signal amplitude bin b from a previous filter coefficient estimate $T_{qi-1}(b)$ in accordance with the equation:

$$T_{qi}(b)=T_{qi-1}(b)+\mu_q\cdot\frac{1}{N_b}\cdot\sum_{|x_{k-q}|\in M_b}\frac{x_k-y_k}{|x_{k-q}|^2}\cdot x_{k-q}^*$$

where

μ_q is a predetermined constant associated with filter tap q,

N_b is the number of stored input signal samples that have an amplitude that falls within a predetermined window M_b around the center amplitude of bin b,

x_{k-q} is a stored input signal sample that has a delay q,

y_k is a power amplifier output signal feedback sample corresponding to input signal sample x_k,

* denotes complex conjugation.

10. The pre-distorter of claim 8, including means (48) for calculating a refined filter coefficient estimate $T_{qi}(b)$ corresponding to a filter tap with a delay q and a signal amplitude bin b from a previous filter coefficient estimate $T_{qi-1}(b)$ in accordance with the equation:

$$\begin{cases} T_{qi}(b)=T_{qi-1}(b)+\mu_q\cdot u(b)\frac{1}{N_b}\cdot\sum_{|x_{k-q}|\in M_b}(x_k-y_k)\cdot x_{k-q}^* \\ u(b)=\frac{1}{\overline{|x_b|}^2} \end{cases}$$

where

μ_q is a constant associated with filter tap q,

N_b is the number of stored input signal samples that have an amplitude that falls within a predetermined window M_b around the center amplitude $\overline{|x_b|}$ of bin b,

x_{k-q} is a stored input signal sample that has a delay q,

y_k is a power amplifier output signal feedback sample corresponding to input signal sample x_k,

* denotes complex conjugation.

11. The pre-distorter of claim 8, including means (48) for calculating a refined filter coefficient estimate $T_{ql}(b)$ corresponding to a filter tap with a delay q and a signal amplitude bin b from a previous filter coefficient estimate $T_{ql-1}(b)$ in accordance with the equation:

$$T_{ql}(b) = T_{ql-1}(b) + \mu_q \cdot (x_k - y_k) \cdot \frac{x_{k-q}^*}{\left|x_{k-q}\right|^2} : \quad \left|x_{k-q}\right| \in M_b$$

where

μ_q is a constant associated with filter tap q,

x_{k-q} is a stored input signal sample that has that has a delay q and an amplitude that falls within a predetermined window M_b around the center amplitude of bin b,

y_k is a power amplifier output signal feedback sample corresponding to input signal sample x_k,

* denotes complex conjugation.

12. The pre-distorter of claim 8, including means (48) for calculating a refined filter coefficient estimate $T_{ql}(b)$ corresponding to a filter tap with a delay q and a signal amplitude bin b from a previous filter coefficient estimate $T_{ql-1}(b)$ in accordance with the equation:

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$$\begin{cases} T_{ql}(b) = T_{ql-1}(b) + \mu_q \cdot u(b) \cdot (x_k - y_k) \cdot x^{*}_{k-q} : & |x_{k-q}| \in M_b \\ u(b) = \dfrac{1}{\overline{|x_b|}^2} \end{cases}$$

where

μ_q is a constant associated with filter tap q,

x_{k-q} is a stored input signal sample that has a delay q and an amplitude that falls within a predetermined window M_b around the center amplitude $\overline{|x_b|}$ of bin b,

x_k is a power amplifier input signal sample that y_{k-q} is a power amplifier output signal feedback sample corresponding to input signal sample x_k,

* denotes complex conjugation.

13. A power amplifier having a pre-distorter formed by a FIR filter structure including

an individual look-up table for each filter tap, each look-up table representing a discretized polynomial in a variable representing input signal amplitude, and

means for selecting, from each filter tap look-up table, a filter coefficient that depends on the amplitude of a corresponding complex signal value to be multiplied by the filter tap, said pre-distorter including

means (50) for storing measured unamplified input signal samples and corresponding power amplifier output feedback signal samples; and

means (48) for determining look-up table filter coefficients for each filter tap by separate independent iterative procedures using said stored samples.

14. The power amplifier of claim 13, including means (48, 50) for implementing said iterative procedures as least mean square based iterative procedures.

15. The power amplifier of claim 14, including means (48) for calculating a refined filter coefficient estimate $T_{qi}(b)$ corresponding to a filter tap with a delay q and a signal amplitude bin b from a previous filter coefficient estimate $T_{qi-1}(b)$ in accordance with the equation:

$$T_{qi}(b) = T_{qi-1}(b) + \mu_q \cdot \frac{1}{N_b} \cdot \sum_{|x_{k-q}| \in M_b} \frac{x_k - y_k}{|x_{k-q}|^2} \cdot x_{k-q}^*$$

where

μ_q is a predetermined constant associated with filter tap q,

N_b is the number of stored input signal samples that have an amplitude that falls within a predetermined window M_b around the center amplitude of bin b,

x_{k-q} is a stored input signal sample that has a delay q,

y_k is a power amplifier output signal feedback sample corresponding to input signal sample x_k,

* denotes complex conjugation.

16. The power amplifier of claim 14, including means (48) for calculating a refined filter coefficient estimate $T_{qi}(b)$ corresponding to a filter tap with a delay q and a signal amplitude bin b from a previous filter coefficient estimate $T_{qi-1}(b)$ in accordance with the equation:

$$\begin{cases} T_{qi}(b) = T_{qi-1}(b) + \mu_q \cdot u(b) \dfrac{1}{N_b} \cdot \displaystyle\sum_{|x_{k-q}| \in M_b} (x_k - y_k) \cdot x_{k-q}^* \\ u(b) = \dfrac{1}{\overline{|x_b|}^2} \end{cases}$$

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where

μ_q is a constant associated with filter tap q,

N_b is the number of stored input signal samples that have an amplitude that falls within a predetermined window M_b around the center amplitude $\overline{|x_b|}$ of bin b,

x_{k-q} is a stored input signal sample that has a delay q,

y_k is a power amplifier output signal feedback sample corresponding to input signal sample x_k,

* denotes complex conjugation.

17. The power amplifier of claim 14, including means (48) for calculating a refined filter coefficient estimate $T_{ql}(b)$ corresponding to a filter tap with a delay q and a signal amplitude bin b from a previous filter coefficient estimate $T_{ql-1}(b)$ in accordance with the equation:

$$T_{ql}(b) = T_{ql-1}(b) + \mu_q \cdot (x_k - y_k) \cdot \frac{x^*_{k-q}}{|x_{k-q}|^2} : \quad |x_{k-q}| \in M_b$$

where

μ_q is a constant associated with filter tap q,

x_{k-q} is a stored input signal sample that has that has a delay q and an amplitude that falls within a predetermined window M_b around the center amplitude of bin b,

y_k is a power amplifier output signal feedback sample corresponding to input signal sample x_k,

* denotes complex conjugation.

18. The power amplifier of claim 14, including means (48) for calculating a refined filter coefficient estimate $T_{ql}(b)$ corresponding to a filter tap with a

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delay q and a signal amplitude bin b from a previous filter coefficient estimate $T_{qi-1}(b)$ in accordance with the equation:

$$\begin{cases} T_{qi}(b) = T_{qi-1}(b) + \mu_q \cdot u(b) \cdot (x_k - y_k) \cdot x_{k-q}^{*} : & |x_{k-q}| \in M_b \\ u(b) = \dfrac{1}{\left|\overline{x_b}\right|^2} \end{cases}$$

where

μ_q is a constant associated with filter tap q,

x_{k-q} is a stored input signal sample that has a delay q and an amplitude that falls within a predetermined window M_b around the center amplitude $\left|\overline{x_b}\right|$ of bin b,

x_k is a power amplifier input signal sample that y_{k-q} is a power amplifier output signal feedback sample corresponding to input signal sample x_k,

* denotes complex conjugation.

19. A base station provided with a power amplifier having a pre-distorter formed by a FIR filter structure including

an individual look-up table for each filter tap, each look-up table representing a discretized polynomial in a variable representing input signal amplitude, and

means for selecting, from each filter tap look-up table, a filter coefficient that depends on the amplitude of a corresponding complex signal value to be multiplied by the filter tap, said pre-distorter including

means (50) for storing measured unamplified input signal samples and corresponding power amplifier output signal feedback samples; and

means (48) for determining look-up table filter coefficients for each filter tap by separate independent iterative procedures using said stored samples.

20. The base station of claim 19, including means (48, 50) for implementing said iterative procedures as least mean square based iterative procedures.

21. The base station of claim 20, including means (48) for calculating a refined filter coefficient estimate $T_{ql}(b)$ corresponding to a filter tap with a delay q and a signal amplitude bin b from a previous filter coefficient estimate $T_{ql-1}(b)$ in accordance with the equation:

$$T_{ql}(b) = T_{ql-1}(b) + \mu_q \cdot \frac{1}{N_b} \cdot \sum_{|x_{k-q}| \in M_b} \frac{x_k - y_k}{|x_{k-q}|^2} \cdot x_{k-q}^*$$

where

μ_q is a predetermined constant associated with filter tap q,

N_b is the number of stored input signal samples that have an amplitude that falls within a predetermined window M_b around the center amplitude of bin b,

x_{k-q} is a stored input signal sample that has a delay q,

y_k is a power amplifier output signal feedback sample corresponding to input signal sample x_k,

* denotes complex conjugation.

22. The base station of claim 20, including means (48) for calculating a refined filter coefficient estimate $T_{ql}(b)$ corresponding to a filter tap with a delay q and a signal amplitude bin b from a previous filter coefficient estimate $T_{ql-1}(b)$ in accordance with the equation:

$$\begin{cases} T_{qi}(b) = T_{qi-1}(b) + \mu_q \cdot u(b) \dfrac{1}{N_b} \cdot \sum\limits_{|x_{k-q}| \in M_b} (x_k - y_k) \cdot x_{k-q}^* \\ u(b) = \dfrac{1}{\overline{|x_b|}^2} \end{cases}$$

where

μ_q is a constant associated with filter tap q,

N_b is the number of stored input signal samples that have an amplitude that falls within a predetermined window M_b around the center amplitude $\overline{|x_b|}$ of bin b,

x_{k-q} is a stored input signal sample that has a delay q,

y_k is a power amplifier output signal feedback sample corresponding to input signal sample x_k,

* denotes complex conjugation.

23. The base station of claim 20, including means (48) for calculating a refined filter coefficient estimate $T_{qi}(b)$ corresponding to a filter tap with a delay q and a signal amplitude bin b from a previous filter coefficient estimate $T_{qi-1}(b)$ in accordance with the equation:

$$T_{qi}(b) = T_{qi-1}(b) + \mu_q \cdot (x_k - y_k) \cdot \frac{x_{k-q}^*}{|x_{k-q}|^2} : \quad |x_{k-q}| \in M_b$$

where

μ_q is a constant associated with filter tap q,

x_{k-q} is a stored input signal sample that has that has a delay q and an amplitude that falls within a predetermined window M_b around the center amplitude of bin b,

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y_k is a power amplifier output signal feedback sample corresponding to input signal sample x_k,

* denotes complex conjugation.

24. The base station of claim 20, including means (48) for calculating a refined filter coefficient estimate $T_{qi}(b)$ corresponding to a filter tap with a delay q and a signal amplitude bin b from a previous filter coefficient estimate $T_{qi-1}(b)$ in accordance with the equation:

$$\begin{cases} T_{qi}(b) = T_{qi-1}(b) + \mu_q \cdot u(b) \cdot (x_k - y_k) \cdot x_{k-q}^* : \quad |x_{k-q}| \in M_b \\ u(b) = \dfrac{1}{\overline{|x_b|}^2} \end{cases}$$

where

μ_q is a constant associated with filter tap q,

x_{k-q} is a stored input signal sample that has a delay q and an amplitude that falls within a predetermined window M_b around the center amplitude $\overline{|x_b|}$ of bin b,

x_k is a power amplifier input signal sample that y_{k-q} is a power amplifier output signal feedback sample corresponding to input signal sample x_k,

* denotes complex conjugation.
